CALIFORNIA
AGRICULTURAL EXTENSION SERVICE

CIRCULAR 55
JUNE, 1931

Growing and Handling Sweet Potatoes in California

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Cooperative Extension work in Agriculture and Home Economics, College of Agriculture, University of California, and United States Department of Agriculture cooperating. Distributed in furtherance of the Acts of Congress of May 8 and June 30, 1914. B. H. Crocheron, Director, California Agricultural Extension Service.

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BERKELEY, CALIFORNIA

GROWING AND HANDLING SWEET POTATOES IN CALIFORNIA

D. R. PORTER[1]

INTRODUCTION

During the nine-year period from 1920 to 1928 inclusive, the per capita production of sweet potatoes in the United States was approximately 45 pounds. In California, during the same period, the per capita production was only about ten pounds. Although the people of California perhaps do not consume this commodity to the same extent as those of southern and eastern states, yet these data suggest that the state produces insufficient sweet potatoes to supply the local demand.

Although there appears to be a condition of under production of sweet potatoes in California, it is a fact that in 1927 and 1928, 405 and 335 carloads, respectively, were shipped from California to San Antonio, Portland, Seattle, Salt Lake City and Spokane. In 1927, 61 per cent, and in 1928, 74 per cent of the California carlot shipments moved during the months of August, September, October and November, that is, during the harvesting season.

Probably one reason why so much of the California crop is shipped from the state is that a relatively low per cent of the crop is stored. This condition does not exist in many of the southern and eastern states. In 1928, 60 per cent of the California shipments moved during September, October and November, while in Delaware only six per cent moved during these three months. Much of the crop produced in New Jersey, Maryland, North Carolina, Tennessee, and Louisiana moves after January 1. In these states, growers have learned that the more profitable procedure is usually to store their crop until the market price is higher than at digging time. The development of adequate storage facilities in California might make possible the disposal of practically the entire crop within the state. In order to store sweet potatoes with profit, however, the grower must understand not only storage practices but control of the diseases which attack the potatoes while in storage. As many of these diseases originate in the hotbed and field, he should understand the relation of cultural practices and varieties to the more important sweet potato diseases.

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SWEET POTATO DISTRICTS OF CALIFORNIA

The largest acreage of sweet potatoes in California is localized near the main line of the Southern Pacific railway in Merced and Stanislaus counties in the San Joaquin Valley. Although the data in table 1 show

TABLE 1

STATISTICAL SUMMARY OF SWEET POTATO PRODUCTION IN CALIFORNIA

Year	Acreage: Total (approximate)	Acreage: Per cent of U. S.	Yield: Total tons	Yield: Per acre for California tons	Yield: Per acre for U. S. tons	Carlot shipments: Total cars	Carlot shipments: Per cent originating in Stanislaus and Merced Counties
1920	8,000	0.8	2,540	3.49	2.89	860	....
1921	8,000	0.5	2,400	3.30	2.56	919	....
1922	8,000	0.7	2,200	3.02	2.69	936	....
1923	6,000	0.6	1,725	3.16	2.69	862	99.7
1924	6,000	0.9	1,695	3.11	2.18	484	96.7
1925	9,000	1.1	2,767	3.38	2.20	948	96.4
1926	12,000	1.4	2,910	2.66	2.78	1,096	96.4
1927	12,000	1.3	2,700	2.48	2.78	1,042	99.6
1928	12,000	1.5	2,880	2.64	2.64	740	99.0
1929	10,000	1.2	2,475	2.73	2.84	796	98.9

that from 1923 to 1929 over 97 per cent of the carlot shipments from California originated in these two counties, they do not indicate the volume of truck movement nor the volume sold at roadside markets. Much of the crop moves to market by truck, particularly in the territory near Los Angeles, Bakersfield, Santa Ana, and Fresno. During the period from 1920 to 1929 carlot shipments originated in the following counties: Merced, Stanislaus, San Joaquin, Kern, Kings, Shasta, Fresno, Imperial, Colusa, Los Angeles, and San Diego. In certain other districts a relatively small volume of sweet potatoes is grown and marketed locally.

PLANT REQUIREMENTS

Temperature.—The sweet potato plant requires a long, warm growing season where the mean summer temperature is above 72° Fahr. and the frost-free period not less than 125 days. Being native to the tropics, the plant thrives in a subtropical climate where the night temperatures are high enough not to chill it. The plant is very sensitive to frost and therefore cannot be set in the open field until

danger from that source is over. Because the tops are also killed by the first heavy frost in the fall, the crop should be dug before or soon after frost. The normal development of the plant is retarded by cool, cloudy weather during the growing season and regions having cold nights during the summer are not favorable. Under favorable conditions, sweet potato culture in the United States exists farther north than one would naturally suppose, being common to certain regions in New Jersey, Indiana, Illinois, Iowa and Washington; and although early frosts in the fall often lower the yeld, the crop is grown with profit in those states. The cool nights, common to coastal sections of California, make it impractical to attempt to grow sweet potatoes near the coast, except south of Los Angeles. Experimentally, sweet potato plants will remain normal at a constant soil temperature of 60° F but will make very little growth. If held at 50° the plants soon die. Growth increases as the soil temperature is raised to 95° F, but above that point is retarded.

Moisture.—Many growers believe that the sweet potato is relatively drought-resistant and though it probably uses as much water as any other plant having the same amount of foliage and grown under identical conditions, it is indeed not seriously injured by rather long periods of drought. Young plants intended for transplanting are often shipped long distances and yet under favorable conditions are able to make rapid growth. In the Turlock district of California, excellent crops have been grown on sandy land without irrigation, but such soils are sub-irrigated to some extent.

Soil Types.—The physical texture of the soil seems to affect the form, size, and smoothness of the potatoes. Top growth is usually excessive in the heavier soils, retarding maturity and causing inconvenience in digging. Generally, light sandy loam and coarse sandy soils are most suitable, particularly for such varieties as Yellow Jersey, Prolific, and Priestly. The detrimental effects of fine-textured soils seem to be more marked toward the northern limits of culture. Sandy soils have the advantage of retaining less of the irrigation water than do heavy soils, so that plants growing in sandy soils suffer less from excessive moisture. On the heavier soils the varieties Nancy Hall, Porto Rico, and some of the large white varieties develop more satisfactorily than those of the Jersey group. In general, sweet potatoes are fairly tolerant of slightly acid soil; but if the soil is too acid lime will prove beneficial. Under California conditions, the crop may be matured in the early fall by withholding irrigation water, thus drying out the potatoes in the soil, making it possible to take advantage of the early market if desired.

THE SEED

The term "seed" as applied to sweet potatoes is a misnomer, just as in the case of Irish potatoes. True seed, developing from flowers and fruit, is seldom seen in the United States, although it has been known to form in southern Florida. Occasionally sweet potatoes bloom in southern California, but seed is rarely formed. However, "seed" has such a universal meaning among growers that it will be used in this discussion to mean the enlarged portions of the root, commonly known as sweet potatoes. Probably one of the limiting factors in the production of a profitable crop of sweet potatoes is the inability to secure good seed in those states where seed certification is not practiced. In California neither the demand for certified seed nor the acreage grown at present seems to justify certification. With proper precautions it is possible for the grower to select high quality seed from his own fields.

The sweet potato itself consists of a root, originally a fibrous feeding root, which in the process of development has thickened for a greater or less distance from the central stem. On each such thickened root, or potato, are found four rows of lateral fibrous feeding roots, which usually disappear before the crop is mature, leaving only slight depressions where they were attached. From the neighborhood of the root scars, adventitious buds originate and under favorable growing conditions, sprouts are formed. These sprouts have an independent root system and are only weakly connected with the mother potato, from which, however, they derive most of their nourishment until they are separated and set in the open field. The sweet potato has no true rest period, for the sprouts may start growing at any time under suitable moisture and temperature conditions and often do so in the field when harvesting is delayed and in the storage house in the later part of the storage season.

For seed purposes the smaller potatoes, ranging from one to two inches in diameter, are most often used. Larger potatoes, although they may be used, require more space in the hotbed and produce fewer plants, for their area, than smaller ones. Larger potatoes if used for seed stock may be split lengthwise and placed in the hotbed with the flat side down. The amount of seed necessary to produce sufficient plants for an acre of land varies with the variety, the amount of disease present, the proper care of the hotbed, and the spacing of the plants in the field. If all possible precautions are observed 150 pounds

of Yellow Jersey or 200 pounds of Nancy Hall seed should produce enough plants for an acre.

Another method of producing plants is to cut runners from plants growing in the field and transplant them into moist soil. Roots, some of which become thickened into fleshy roots, then develop promptly from the nodes below the surface of the soil. Frequently these cuttings are superior to plants produced in the hotbed because they are likely to be more nearly free of diseases. This practice is rather common in some sections of the South and is followed to a limited extent in California. Its practicability is limited to sections having a long growing season and to sections where storage of the table stock is practiced, as the crop produced by vine cuttings is apt to mature late when the price is low.

Seed Selection.—Seed stock should be selected in the fall of the year either before or during harvesting (figs. 1 and 2). The plant, rather than the potato, should be the basis of selection and should be chosen from the standpoint of freedom from disease. Probably no appreciable advantage will be gained by selecting seed stock of desirable type, for the sweet potato is propagated vegetatively, and little if any variation is likely to occur among individual plants. There has been a prevalent idea that desirable type could be maintained by selecting potatoes for seed from hills which produced the ideal type. Recent work, however, has indicated that this practice rarely accomplishes the desired results. *The important consideration in sweet potato seed stock selection is to select potatoes from hills which are visibly free of disease*, particularly stem rot and black rot. Plants infected with stem rot often produce small potatoes in great abundance, and if these are used for seed stock, the succeeding crop yield will be materially reduced by this disease. Small potatoes from plants free of stem rot are, however, particularly desirable as seed stock, for as previously pointed out the small potatoes produce relatively more plants than large potatoes. The grower who attempts to select his seed stock from the general run of potatoes in the storage house is taking considerable risk.

Successful growers usually select their seed stock in advance of the regular harvest. A few rows are plowed out at a time, and the central stem of each plant is split lengthwise from the crown of the plant downward. If the interior of the stem is normal in color, showing no yellow, brown or black discoloration, the plant is probably healthy. Seed selected in this manner should be stored in new or in disinfected boxes. Such selected seed is likely to keep well in storage. This statement is confirmed by some data obtained from an

experiment conducted in Stanislaus County in the fall of 1929. Seed selected from plants not visibly infected with any disease was placed in storage for comparison with seed which was selected at random in the same field where the hill-selected seed was secured. These two

Fig. 1.—Selecting seed from cull pile in the field—the wrong way to get healthy seed.

Fig. 2.—The right way to select seed sweet potatoes. The hills are laid out, and the stem of each plant is examined for disease.

lots of seed were placed side by side in the storage house in October and were removed and sorted in March just in time to be placed in the hotbed. Examination showed that 75 per cent of the hill-selected seed was free from rot, while only 58 per cent of the "field run" stock

was fit to place in the hotbed. Thus, in addition to relative freedom from stem rot, hill-selected seed may be subject to less rot during the storage period than seed selected at random.

Seed Disinfection.—Sweet potato seed disinfection serves to destroy the disease-producing microorganisms which may be lodged on the surface of the seed. The most common seed-borne disease-producing organisms are those responsible for stem rot, black rot, scurf and foot rot. In extreme instances of infection these organisms may be lodged beneath the skin of the potato, and in such instances they are not killed by seed disinfection. Extreme cases of black rot and scurf may be obvious and potatoes so infected may be discarded when the seed is sorted over. In the event that the stem-rot producing organism is lodged inside the potato its presence is not apparent and such seed is often placed in the hotbed. Stem-rot infected seed must therefore be detected and discarded at harvest time. In like manner, seed visibly infected with other diseases may be discarded before storage, thus eliminating sources of infection for decay in the storage house. Remember disinfection is most effective when practiced in conjunction with seed selection, sanitation, and crop rotation. Seed disinfection is only one of the many measures of precaution observed by the more successful grower and may be considered not only cheap but effective insurance against preventable losses in the field, in the storage house, and in transit. The seed-borne diseases are discussed in detail elsewhere in this circular.

The most commonly used sweet potato disinfectant is corrosive sublimate (mercuric chloride). Its effectiveness was discovered many years ago by workers in the United States Department of Agriculture and the extent of its application by sweet potato growers is adequate evidence of its usability. This chemical is dissolved in water at the rate of one ounce of corrosive sublimate to eight gallons of water. After soaking in this solution for ten minutes the potatoes are bedded. Corrosive sublimate dissolves very slowly in cold water but very readily in water heated to 125° F. Fairly rapid solution may be obtained even in cold water by adding about one pound of common table salt to a gallon of water and then adding the corrosive sublimate. Hot water, without the salt, is to be preferred, however. As the sublimate is corrosive to metal, containers of glass, wood or of earthenware should be used. *Being poisonous, the solution should be used cautiously and should not be left in a place accessible to animals.*

Wooden barrels are particularly adaptable to farm use, the number depending upon the quantity of seed to be disinfected and the number of laborers employed to place the treated potatoes in the

beds. A bushel crate, basket or hamper may be used as a receptacle for dipping the seed in the solution (fig. 3). As grain or gunny sacks remove a considerable amount of the corrosive sublimate from the solution their use as dipping containers is inadvisable. Corrosive sublimate solution weakens with use but its strength may be kept approximately normal by the following plan: After each ten bushels of potatoes treated, add two-fifth to one-half ounce of mercuric

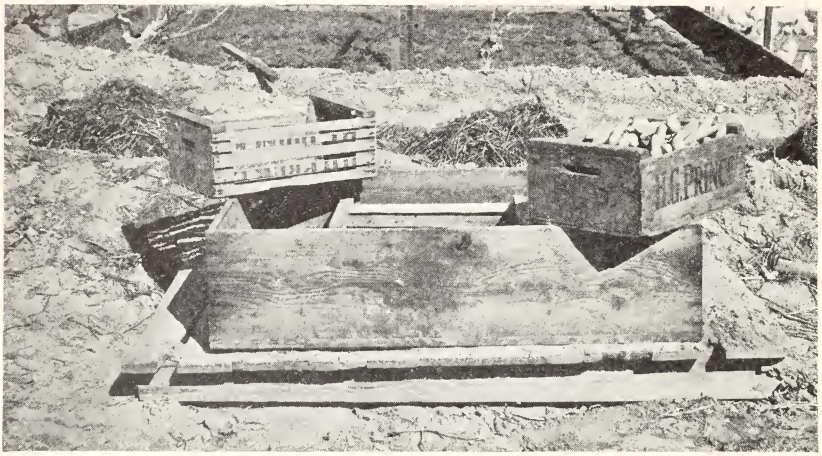

Fig. 3.—Seed disinfecting equipment. The water-tight box is filled with a solution of mercury bichloride and the sweet potatoes soaked for 10 minutes just before bedding.

chloride and enough water to restore the solution to its original volume. The solution should be discarded after the treatment of about 500 bushels.

In certain sections of the United States, some of the organic mercury compounds (Semesan Bel) have proved effective as sweet potato disinfectants. When added to water they serve the same purpose as corrosive sublimate. They do not corrode metal (except aluminum) and the solution (suspension) does not lose strength during continued use. They have not been tried extensively in California, but their advantages over corrosive sublimate warrant investigation. Growers would do well to try them on a small scale in comparison with corrosive sublimate.

PREPARATION AND CARE OF THE HOTBED

The type of hotbed is usually determined by the source of heat to be used in sprouting the plants. Regardless of the source of heat, the bed should be located in a warm, sunny, well-drained spot, protected from cold winds by a fence or windbreak. If fresh stable manure is used as a source of heat, the following directions, modified to suit local conditions, may be followed to advantage. A trench is dug six to eight feet wide, fifteen inches deep, and as long as necessary to accommodate the quantity of seed to be bedded. When plants are to be grown for a relatively large acreage (over 20 acres) the more convenient plan is usually to arrange the beds in short sections parallel to each other. Several days before the potatoes are placed in the bed, the trench is filled with fresh, heating horse manure, packed by tramping, and then covered with a layer of three to four inches of sandy soil or sand which has been secured from a location where sweet potatoes have never been grown. This sand is then leveled and when it has become warm the disinfected potatoes are laid on it about one-half inch apart, and are covered at once to a depth of three inches with disease-free sand. Because the young plants obtain the necessary nutriment for their development from the mother potato, there is no need for fertile soil in the plant bed. Sand, furthermore, does not bake and crust in such a way as to prevent the emergence of the young plants, and the formation of fibrous roots is much more extensive in sand than in heavier soils. This last is an important consideration, especially with the variety Nancy Hall, whose plants form roots sparingly and are therefore difficult to transplant successfully. The young plants are also more easily removed from the plant bed when sand is used instead of heavier soil.

Sand, however, has certain disadvantages when not used intelligently in the hotbed. The chief difficulty is that it dries out rapidly and soon becomes very hot when exposed to the direct rays of the sun, often inducing severe burning of the succulent young plants. Danger from such burning may be avoided by shading the bed with lumber or canvas and by proper attention to the time of watering. Injury caused by burning is sometimes wrongly attributed to the black-rot organism.

After the potatoes have been bedded the temperature of the sand in the hotbed should be carefully watched and should be maintained as nearly as possible at 75° to 85° F. Although a temperature of 90° has not proved particularly dangerous, and although the plants will

tolerate a temperature near 100° for a very short time, it is much safer to keep the temperature at or below 85° F whenever possible. A reliable thermometer should be placed in the sand with the bulb about two inches below the surface. It is well to read the temperature at several places in the bed for the manure does not heat evenly. After the plants have emerged, the temperature should be lowered slightly to prevent the plants from becoming too succulent and tender for they survive transplanting to the open field much better if first hardened off.

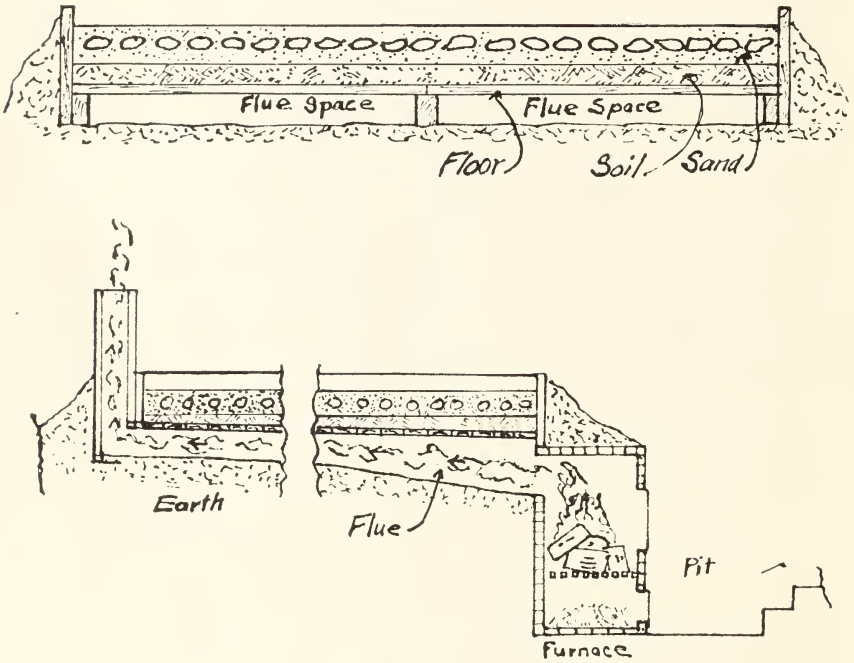

Fig. 4.—Fire-heated hotbed. Above is shown a cross-section of the bed. The flue-space extends the entire width and length of the bed and is covered with rough flooring. Over this a layer of tamped soil or clay from 3 to 6 inches deep, above which is the sand in which the potatoes are bedded. Below is shown a side-section, showing arrangement of furnace and flue.

The practice of applying a top dressing of manure or commercial fertilizer to the hotbed soil is to be discouraged. Not only is this form of nourishment unnecessary for the production of normal plants, but its application often results in burning.

In the cooler sections, sweet potato beds are enclosed by a frame of 1 by 12-inch boards and covered with lumber, glazed sash or unbleached muslin cloth, waterproofed with hot, raw linseed oil. In the warmer sections, including the Turlock district and the lower

San Joaquin Valley, the beds are seldom enclosed, but are covered with board shutters three to four feet wide and slightly longer than the width of the bed. These shutters are placed on the surface of the beds at bedding time in order to retain the heat. After the sand in the bed has become warm, and danger of overheating is likely, the shutters are removed from time to time to regulate the temperature. They are permanently removed when the plants begin to emerge.

Where sufficient quantities of fresh stable manure cannot easily be obtained as a source of heat for the hotbed, other methods of

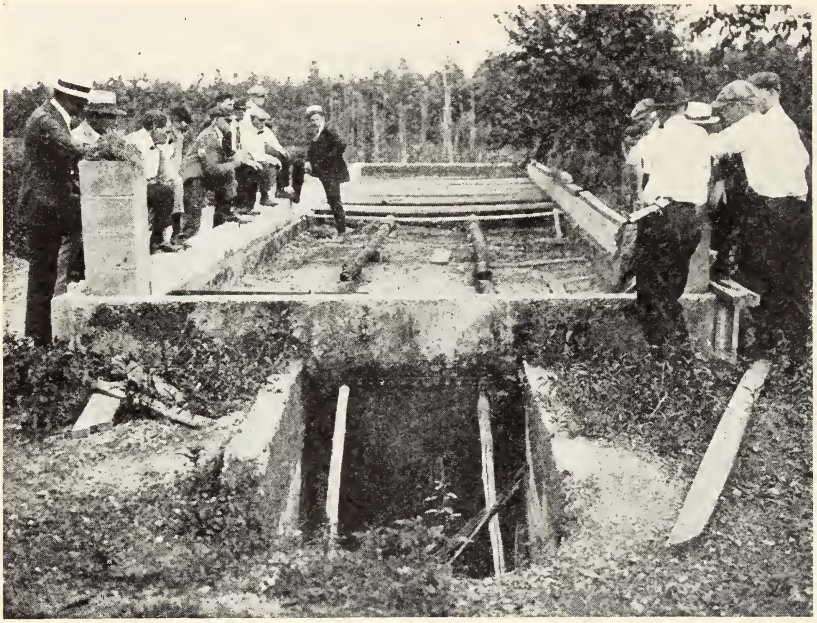

Fig. 5.—Top view of fire-heated hotbed, concrete construction. (Courtesy, New Jersey Exp. Sta.)

heating are resorted to. The flue-heated bed, one type of which is shown in figures 4 and 5, is well suited for growing the plants. A pit is located at one end and recessed beneath the bed. Opening into this pit is a brick furnace which may be equipped with a grate for burning coal or other fuel. The smoke, fumes and heat from the firebox are conducted beneath the plant bed, either through flues spaced three feet apart and entering a chimney at the far end through a header; or the hotbed may have a tight floor, with an open space beneath, extending for its entire length and width and connected with a chimney at the far end. Heaters of either the above types may accommodate beds 8 to 12 feet wide and 40 feet long. For larger beds

the use of coils of pipe for steam or hot-water heating may be more economical.

Sanitation is one of the most important considerations to be observed in connection with the preparation of the hotbed. Often growers who have a sheltered area where there is little danger of either extreme cold or heat naturally wish to use this spot for the hotbed from year to year. Other growers who enclose their hotbeds in wooden frames prefer not to move the frames from one place to another. Those growers who use flue-heated hotbeds likewise find it inconvenient to move the beds. This practice, however, if followed without proper precautions, often results in heavy losses through disease, for the manure used as a source of heat for sweet potato plants provides ideal food materials for the disease-producing organisms. The following recommendation is therefore made: Remove and haul away all sand and manure as soon as all the plants are pulled. The heat and drought of the long summer will tend to prevent multiplication of the disease-producing organisms. When the beds are being made ready for another crop, disinfect the old trench and frame and the soil surrounding the beds with either formaldehyde or copper sulfate. Formaldehyde should be used at the rate of 1 pint in 30 gallons of water and two applications made at intervals of 24 hours. Copper sulfate should be used at the rate of 4 pounds in 50 gallons of water.

PREPARATION OF THE SOIL

The exact details of culture for sweet potatoes vary in different localities in California. A few general suggestions may, however, be useful to the prospective grower who has had little experience with this crop.

The plants are usually planted on ridges from 8 to 15 inches high, the lower ridges being generally preferred. Ridge-culture, as compared with flat-culture, provides more favorable conditions for the development of the roots, facilitates row irrigation and reduces labor of harvesting. The rows are generally marked off three feet apart and the ridges formed with a plow or lister. The ridging disk cultivator can also be used to form ridges after all but the two inner disks have been removed and set at the proper angle to form a ridge between them. In the event a transplanting machine is used the tops of the ridges are smoothed slightly with a plank drag before the plants are set.

The spacing of the plants in the row should be varied to suit conditions. Varieties such the Nancy Hall, which have a tendency to form extremely large potatoes, should be set much closer than those which tend to produce a larger number of medium-sized potatoes, as do various strains of the Jersey group. The spacing is also influenced by the soil fertility, the plants being set closer on relatively fertile than on poorer soils. The average distance between plants in the row is 15 inches, but this distance may be shortened to 10 or increased to 18, according to the soil fertility.

FERTILIZERS

While the soil fertility necessary to produce a profitable crop is perhaps not so high as for some other truck crops, yet some of the sandy soils on which sweet potatoes are now grown would doubtless produce larger crops if organic matter and certain types of commercial fertilizer were added. On some of the long-cultivated sandy soils in the East, South, and Middle West, sweet potatoes respond markedly to the application of various fertilizer ingredients. The kind of fertilizer necessary for a given field must be determined experimentally, although in general, the sweet potato plant requires phosphorus and potassium in excess of nitrogen.

Manure, if used, should contain no refuse from the sweet potato crop of the previous season. Potatoes severely infected with black rot and the remains of plants infected with stem rot are sometimes fed to hogs and cattle and the manure used as fertilizer. Obviously this practice tends to spread these diseases. Commercial fertilizers, if used, should be applied long enough before transplanting so that they begin to dissolve in the soil, otherwise severe burning may occur when the plant root comes in contact with the fertilizer.

Fertilizer trials in the East and South have indicated that, in general, excessive nitrogen tends to result in the production of long slender potatoes, while potassium tends to produce more blocky or chunky potatoes. In addition both potassium and phosphorus tend to increase the yield.

In southern California considerable work has been done with sweet potato fertilizers. The experiments of F. H. Ernst[2] have demonstrated that yield increases due to soil fertilization vary with the type and natural fertility of the soil. The response of sweet potatoes to

[2] Assistant Farm Advisor of Los Angeles County. The results of his trials appear in tables 2 and 3.

soil fertilizers in 1930 is indicated in table 2. On relatively infertile soil, evidently, even moderate applications of certain commercial fertilizers tend to increase the yield. Combined applications of nitrate of soda (200 pounds) and of fish meal (300 pounds per acre) cost $14.00 and increased the yield by 4186 pounds. At two cents per pound this yield increase represents a profit of approximately $70.00 per acre. On very fertile soil (trial No. 2 in table 1) the increased yield was only 1060 pounds per acre; but at two cents per pound for the potatoes the fertilizer yielded a net profit of $7.20 per acre.

TABLE 2

EFFECT ON YIELD OF SWEET POTATO FERTILIZERS IN LOS ANGELES COUNTY, 1930

Fertilizer used	Rate of application, pounds per acre	Trial No. 1*		Trial No. 2		Cost of fertilizer per acre
		Actual yield, pounds per acre	Per cent increase over check	Actual yield, pounds per acre	Per cent increase over check	
None (check)	.....	10,475	....	19,002	....	.....
Nitrate of soda (200) Fish meal (300)	500	14,661	40	20,062	6	$14.00
Nitrate of soda	400	13,025	24	21,549	13	10.00
Nitrate of soda (200) Fish meal (500) Potash (500) Superphosphate (500)	1,700	14,585	39	23,346	23	36.75
Potash (500) Superphosphate (500)	1,000	12,505	19	18,325	–3	22.75

TABLE 3

RESPONSE OF SWEET POTATOES TO SOIL FERTILIZERS IN LOS ANGELES COUNTY IN 1927 AND 1928

Fertilizer used	Number of trials	Yield per acre, pounds	Per cent increase
None (check)	6	16,341	....
Inorganic nitrogen	2	19,229	18
Total nitrogen	5	21,362	31
Nitrogen and potash	5	20,841	27
Potash alone	3	19,482	13

Trials conducted in 1927 and 1928 by Mr. Ernst likewise indicated that yields were markedly increased by soil fertilizers. The summary of his results for these two years appears in table 3, and tends to show that the soil was deficient in some elements necessary for most favorable plant growth.

* Trial No. 1 was conducted on relatively infertile gravelly loam, while trial No. 2 was conducted on very fertile soil which had been cropped with alfalfa during 1927, 1928, and 1929.

TRANSPLANTING

Successful growers begin to transplant into the open field just as soon as danger of frost is past. In the Los Angeles district, transplanting usually begins about April 1 and continues until the first part of June. Some of the objections to late planting are the difficulty of securing a good stand because of the heat, and the reduction of the yield by the shorter growing season. Most growers in California find that the earlier transplantings produce the larger crop.

Plants are pulled from the hotbed one at a time so as not to disturb the mother potato. This caution is especially important if a second pulling must be made from the same bed. After pulling, the plants are kept out of the direct rays of the sun until transplanted, particular care being taken to prevent the roots from drying out. Plants more than ten inches long are pruned by removing the tops in order to facilitate setting in the field. Sweet potato plants may be held for several days after pulling or may be shipped long distances if the roots are wrapped in moistened paper. The tops must be kept dry in order to prevent slimy decay of the leaves and stems.

If a commercial acreage of sweet potatoes is being grown, the plants are usually transplanted by one of several types of machines which are equipped with a tank and an automatic watering device to discharge the desired quantity of water about the roots of each plant as it is set. The amount of water necessary is determined by the condition of the soil, but even though the soil is moist, at least a half-pint of water should be used for each plant. On very sandy soils, which dry out quickly, and when the work is done late in the spring, row irrigation should be given within a day or two after transplanting in order to moisten the ridges and to give the young plants a favorable start before they become dry. Most of the transplanting machines are designed for use either on the tops of the ridges or on the level, and under favorable conditions such machines will make it possible to set from three to four acres per day.

CULTIVATION

The exact details of cultivation for sweet potatoes vary among different localities. A few general suggestions may, however, be useful to the prospective grower of limited experience with this crop.

Cultivation is practicable only in so far as it controls weeds, being of little value in conserving moisture. Young plants thrive to

better advantage if the soil is not allowed to become crusted near the crown. Usually the hoe is needed in destroying weeds between the plants in the row, but a cultivator may be used until the plants have formed long runners. These runners, when first sent out, must be turned so that they will grow along the ridge and not interfere with cultivation between rows. The turning may be done by hand or by means of metal rods attached to the cultivator. Each row should be cultivated in the same direction each time so as to disturb the runners as little as possible. If the vines are allowed to become covered with moist soil between the rows, new roots form and soon small potatoes develop which tend to reduce the yield of the hill. When, eventually, the vines cover the space between the rows, cultivation is discontinued.

IRRIGATION

The time of application and the quantity of water necessary vary with the soil type and locality. If water is used liberally when the plants are set irrigation is usually not necessary for a few days after transplanting, except in extremely sandy soils. On sub-irrigated land, two surface irrigations may advantageously be given shortly after transplanting, while on the higher land about seven irrigations during the growing season are required.

Where sweet potatoes are to be irrigated, the land should be so graded and leveled that the water may be evenly distributed. If the plants receive too much water the potatoes are often over-sized, rough, and even cracked. In addition, black rot is apt to become more severe where too much water is applied.

HARVESTING

The time of harvesting depends upon market conditions, the maturity of the crop being relatively unimportant if the potatoes are to be sold and consumed within a few weeks. Potatoes which are to be stored or shipped long distances must be well matured before digging. Sweet potato plants set in the field in early May will usually mature a crop in August, although the plants will continue growing until killed by frost. The rate of growth of the potatoes has not been determined under California conditions, but the increase in yield during the last few weeks of growth is probably not very great for the early planted crop. During a period in the middle of the season, however, increase in size of the potatoes is very rapid. The vines are

easily injured by a light frost but the potatoes themselves are not injured unless the vines are killed. The sour sap from frozen vines passing down into the potatoes, often provides favorable conditions for decay.

In central California harvesting begins in August, in southern California earlier; while the first sweet potatoes from Imperial Valley reach the market about July 15th. Even the earliest plantings do not produce mature potatoes when harvesting begins but the high price received usually compensates for the smaller yield. Harvesting increases in volume during September and October. Practically all of the sweet potatoes dug before the middle of October are sold on local markets or shipped at once. Those intended for storage are harvested from the middle of October until after the tops have been frosted.

In harvesting, the first operation is to dispose of the tops. Although this is often done entirely by hand by means of long curved knives, many growers prefer to use a pair of disc knives attached to a cultivator set about six to eight inches apart and sufficiently shallow to cut the vines on either side of the crown of the plant without injury to the potatoes. This operation leaves only a little foliage to be cut off with a long-handled curved knife. The tops are then removed and piled in convenient places so that they can later be used to cover the piles of potatoes and thus prevent sunburn.

Various types of machinery are used in removing the potatoes from the soil; some growers prefer a 14-inch moldboard plow. The ordinary Irish-potato digger has not proved successful with sweet potatoes because of the large amount of power required and the excessive bruising of the potatoes. After plowing out, the individual hills are lifted and laid on the ridge to dry. They are then gathered and placed in piles from which the potatoes are "snapped" from the stem, and placed in marketing containers. During clear weather the piled potatoes may be left in the field for a few days, but they should be covered with the vines for protection against frost and sunburn.

As sweet potatoes bruise readily at the time they are dug, extreme care must be exercised during the harvesting operations. Bruised spots not only mar the appearance of the potato, lowering its market value, but likewise serve as points of infection for various rot producing organisms. All unnecessary handling should be avoided.

PACKING, GRADING, AND BRANDING

For many years the standard container for California-grown sweet potatoes was the rectangular crate with a capacity of 100 pounds. Experience has shown, however, that this is too large and too heavy for best results in shipping. In recent years growers in the San Joaquin Valley have made use of a smaller crate with the inside dimensions of 9¾ x 14 x 22½ inches and with a capacity of about 75 pounds. Grading is done in the field. The crate is nearly filled with table stock and then a top layer of uniform-sized potatoes is carefully arranged so as to give a good bulge when the cover is nailed on. The pressure from this bulge holds the potatoes firm, prevents movement within the crate while en route and tends to lessen the injury which would result with a loose pack. Some dealers in the Turlock section have found it profitable to brand their packages. Sweet potatoes to be shipped to nearby cities are not packed in crates but are loaded in the car or on trucks in lug boxes.

STORAGE

Whether sweet potatoes are stored as table stock or as seed stock, the essentials of good storage are the same, with the possible exception of the container used. Table stock is usually stored in bulk, while seed stock can be stored to advantage in boxes or crates. In order to be kept in good condition sweet potatoes should be (1) well matured before digging, (2) carefully handled, (3) cured to drive off excess moisture and to heal bruises, and (4) kept at a uniform temperature after they are cured.

The degree of maturity may be determined by breaking or cutting a few potatoes crosswise and leaving them exposed to the air for a few minutes. The potato is mature if the cut or broken surface dries, but is immature if the cut or broken surface remains moist. Careful handling serves to protect the potatoes from blemishes which mar their appearance and may serve as a point of infection for rot-producing organisms.

Satisfactory methods for the storage of sweet potatoes are of comparatively recent development. The old method of storing in outdoor banks resulted in inferior quality, frost injury and much decay by fungi. Successful curing by the use of artificial heat was the forerunner of the modern method of storage, and since its discovery many

hundreds of curing and storage houses have been erected in sweet potato growing districts. Proper curing is dependent upon proper regulation of heat and of ventilation. The heat tends to dry the potatoes, driving off excess moisture, which adequate ventilation then carries away. The combined effect of heat and ventilation serves to lower the relative humidity, making the surface of the potato less liable to infection.

At the beginning of the storage process the storage house should be kept at a temperature between 80° and 86° F, and provided with enough ventilation to carry the excess moisture away. Such a tempera-

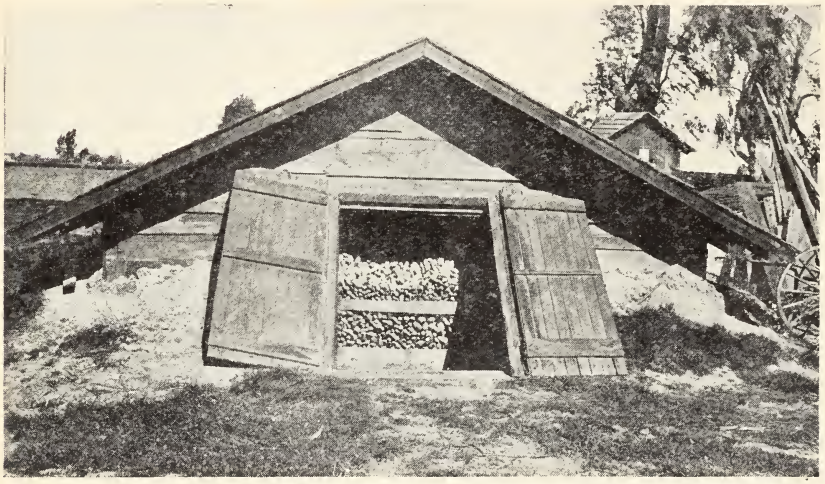

Fig. 6.—A typical sweet potato storage house now in use in the Stanislaus-Merced district.

ture should be maintained for a period of ten days or two weeks, depending somewhat on the length of time necessary to fill the storage house with potatoes.

Ventilation is an absolute necessity even though the temperature may fall below 80° F. The doors and windows of the storage house may be closed at night and on cloudy days, but some of the ventilators in the floor and through the ceiling should be kept open throughout the curing period to prevent the depositing of moisture on the walls. The air, on being warmed, expands and takes up moisture which it gives up on contracting and cooling, and which must then be removed from the house by ventilation.

After the potatoes are thoroughly dried or cured, the temperature should be gradually reduced to 55° F and kept as near that point as possible for the remainder of the storage period. If the temperature

goes below 48° a fire should be started and the temperature raised to 55°. When the temperature goes above 60° the house should be opened in the cool of the day to lower it to 54° or 55° F, and then closed. During mild weather the ventilators in the roof may be partly open all of the time, but they should be closed on cloudy or rainy days. A typical storage house now in use in the Stanislaus-Merced district is shown in figure 6. Ventilation in this type of house is probably adequate but there is no provision for artificial heat after the house is filled with potatoes.

VARIETIES

In the literature may be found the names of over 500 varieties of sweet potatoes. Although many of these names are indeed synonymous or are strictly local in nature, the list is nevertheless far too long. There are probably not more than ten varieties of commercial importance in the United States and not more than five or six in California. The variety Yellow Jersey, for example, is known by at least ten different names.

There are several distinct strains of the Jersey group, differing slightly from one another in color of flesh and of skin. Chief among these strains are Yellow Jersey (commonly known as Little Stem or Little Stem Jersey); Big Stem Jersey; Prolific (also known as Improved Big Stem Jersey); Priestly (a strain of Yellow Jersey); and Red Jersey.

The variety *Yellow Jersey* produces small, slender, long vines; green, hairy and sometimes flattened stems; green leaves hairy on the upper surface; green hairy petioles; dark russet-yellow potatoes, varying in shape, with light yellow to salmon colored flesh. The variety *Big Stem Jersey* produces vines slightly larger than the variety Yellow Jersey, and potatoes with slightly lighter skin and cream colored or almost white flesh. In addition, the leaves are hairy on both the upper and lower surfaces. The variety *Prolific* much resembles Big Stem Jersey in vine characters but the flesh of the potatoes, instead of being cream colored or white, is of a deep salmon color. The *Priestly* vines and potatoes are practically identical with those of Yellow Jersey, but this strain is particularly high yielding and is recommended to growers who prefer the variety Yellow Jersey. As the name indicates *Red Jersey* potatoes have a red skin. When potatoes of the Jersey group are baked the flesh becomes dry and mealy.

The varieties of the Jersey group usually produce well on very sandy soil but are not adapted to the heavier soil types. As a group,

the potatoes adhere strongly to the central stem, the vine growth is not excessive and maturity comes relatively early.

Commercially, the variety *Nancy Hall* is of more recent introduction in California than Yellow Jersey. The vines are shorter than those of the Jersey group and the plants are more bushy in appearance. The leaves which are larger, are prominently tinged with purple at the juncture with the petiole. The potatoes have yellow skin tinged with pink; the flesh is pink while raw becoming golden yellow, moist and very sweet when cooked. This variety is early, productive, and adapted to soil types too heavy for varieties of the Jersey group. Because of the rapid early growth of the potatoes and of their tendency to grow too large, this variety when only half grown can be dug for the extra early crop. The chief objections to the variety Nancy Hall are its tendency to produce large, rough potatoes, and the difficulty in obtaining a satisfactory stand in the field because of the small number of roots formed by the plants in the hotbed.

The variety *Porto Rico* resembles Nancy Hall in habit of growth but has red skin and deep pink flesh which is richly colored, moist and very sweet when cooked. It is important in the Southeast but is not grown extensively in the North or in California.

INSECTS

Fortunately the list of insects causing serious damage to the sweet potato crop is not a long one. The *sweet potato weevil* now a serious pest in some states is not known to occur in California. *Cutworms* frequently destroy young plants soon after they are set in the open field, but they cause no severe damage after the plants have become well established. They may be kept from feeding on the plants by the spreading nearby of a poison bran mash, made by mixing together 20 pounds of bran and 1 pound of paris green, with molasses and water added and mixed to such a consistency that the mash will easily crumble when rubbed between the fingers. The poison should be scattered late in the evening for the cutworms are not active near the surface of the soil during the heat of the day.

DISEASES

Profitable production of sweet potatoes is often dependent upon the intelligent application of control measures for diseases. The crop is subject to loss from diseases which occur in the hotbed, field, storage house and during transportation. Growers wisely make conditions in the hotbed favorable for satisfactory growth of sweet potatoes and in

so doing likewise provide proper growth conditions for many disease-producing organisms. In many sweet potato districts in the United States where the supply of suitable soil is somewhat limited and crop rotation cannot be practiced growers have found by experience that the control of disease very often represents the difference between profit and loss. It has been found by market inspectors at some of the important terminals such as Chicago, Philadelphia and New York that the loss due to rot-producing organisms at work during transit may be as high as 50 per cent. It has been estimated that only 60 per cent of the sweet potato crop is actually consumed, the remaining 40 per cent being a total loss. Granting the authenticity of this estimate, it is strikingly evident that the sweet potato grower who succeeds in minimizing the losses due to disease is the one who makes a substantial profit. The intelligent application of control measures involves an intimate knowledge not only of the disease-producing organism concerned but just as intimate knowledge of the sweet potato plant. It is for this reason that a considerable portion of this circular is devoted to a discussion of sweet potato diseases and their control, with adequate emphasis being placed on the habits and requirements of the sweet potato plant.

Disease-producing Microorganisms.—In order to have a clear understanding of diseases one must know something of the organisms responsible. Growers soon learn the habits of the sweet potato plant and come to understand propagation, culture, varieties, and storage. These agricultural practices become familiar chiefly because the sweet potato plant is large enough to be seen and may be studied as to its response to them. The disease-producing organisms, however, are usually too small to be seen without the aid of a microscope. If these organisms were visible, and if their growth and multiplication could be observed, the grower could better understand and more effectively practice the control measures. For this reason, the following brief description of microorganisms is given.

Essentially the sweet potato plant has much in common with the organism responsible for stem rot or black rot, for the latter is likewise a plant. True, these disease-producing organisms have no visible structures such as leaves, roots, stems, flowers, fruit, and seeds, but they do have root, stem and seed-like structures which serve them much as the leaves and roots serve the sweet potato plant. The root-like structures of the stem-rot organism obtain nourishment much the same as the sweet potato plant draws nourishment from the soil. Being without chlorophyll (the green coloring matter found in the sweet potato and other green plants) these organisms are unable to manu-

facture the food necessary for their existence, and thus must rely on the sweet potato plant for manufactured food. This is why they are known as parasites: they steal the manufactured food which nature intended for the use of the sweet potato plant. While the latter reproduces vegetatively by means of buds on the potatoes, the disease-producing organisms reproduce by means of seed-like structures known as spores, which germinate and infect the sweet potato plant. At one stage in its life cycle, the stem-rot organism is able to live saprophytically on the decaying organic matter common to most soils. The other sweet potato disease-producing organisms differ from the

Fig. 7.—Black rot on sweet potato plants, upon removal from hotbed. (Courtesy, U. S. D. A.)

stem-rot organism in some characters, but essentially resemble it. This limited description will make clearer the following discussion of the more important diseases.

Black Rot.—Black rot of sweet potatoes is probably the most widely distributed disease of this crop. Some of the older growers in New Jersey have stated that they recognized it as early as 1868. It has been found in every state where sweet potatoes are grown commercially, as well as in several foreign countries.

Black rot is encountered in the seed bed, field, storage house and in transit. It attacks the underground parts of the plant (fig. 7), causing yellowing of the foliage, black cankers on the stem below ground, both in the field and hotbed, and somewhat circular depressed

spots of varying sizes on the surface of the potato (fig. 8) either in the ground or in storage and transit. The surface of the spot is of a grayish black color which becomes a dark greenish black when moistened. The organism gains entrance usually through wounds caused by mechanical injuries, by insects, or by the injury caused by a secondary root forming on the surface of the potato or on the stem. After gaining entrance to the potato the organism spreads underneath the skin, enlarging the spot in the center of which spores are produced and serving to permit the dissemination of the disease by means of insects or actual contact with other potatoes. Thus, it is evident that infected potatoes should be discarded and not placed in storage to

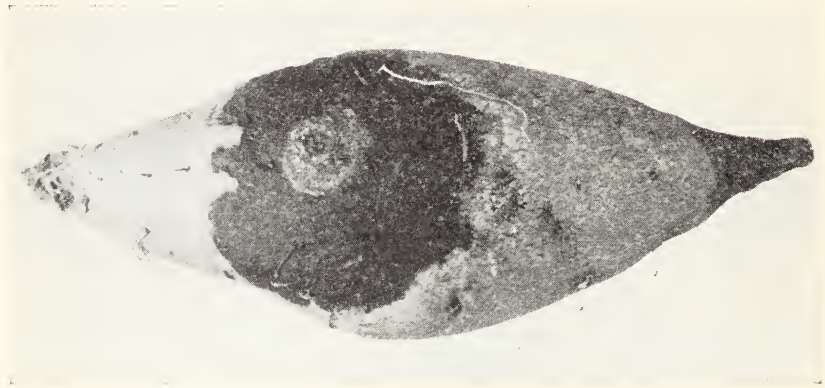

Fig. 8.—Black rot on sweet potato, showing surface decay.
(Courtesy, U. S. D. A.)

serve as centers of infection, and extreme caution should be observed in digging in order to avoid mechanical injuries. As the black-rot organism lives over winter in the soil, the sand used in hotbed preparation should be some in which sweet potatoes have never been grown.

Before adequate control measures were known, black rot was considered the most serious of all sweet potato diseases. During the past fifteen years, however, the application of control measures has proved so effective in some sections of the country that growers fear black rot less than stem rot. These control measures are: (1) hill selection of visibly disease-free seed; (2) proper curing and storage; (3) seed disinfection; (4) sanitation in and around the storage house and seed bed; and (5) rotation of crops. So far as known at present none of the important commercial varieties are appreciably resistant.

Stem Rot.—The term, stem rot, does not adequately describe the disease now generally known by this name, but as growers have learned to recognize it as such, this name will be used in this discussion. Only in an extreme case of infection is the stem visibly rotted.

Stem rot is primarily a disease of the stem and vines although the organism often gains entrance to the potatoes, remaining there in a semi-dormant condition during the storage period. The leaves of infected plants assume a dull, yellowed appearance, often being somewhat puckered, while the white part of the stem becomes faintly purple or blue. Slightly infected plants may escape notice in the hotbed but when transplanted they usually die or become so stunted as not to produce a normal yield of potatoes. The symptoms which develop in the field are similar to those in the hotbed. In extreme cases the entire plant wilts; and as adjoining plants soon cover the

Fig. 9.—Stem rot often affects plants as shown in the center. The vines have died, and sprouts have grown out from the little potatoes already formed.

ground where the plant died, the loss due to stem rot may be underestimated (fig. 9). Other symptoms evident in the field are yellowing of the leaves, swelling and discoloration of the stem below the ground, and yellow, brown or black discoloration inside the stem. In cases of late infection in the field the plant may produce a crop of small potatoes of "seed" size, by means of which the disease is carried over to next year's crop. Infected potatoes may (fig. 10) or may not show internal discoloration at the stem end. Thus the value of hill selection of seed stock in the field at or before harvest becomes evident. The appearance of this disease in "new" localities is usually attributed to shipment of infected potatoes or plants. The stem rot organism can live on decaying organic matter in the soil and may be disseminated by wind, tools, animals, and irrigation water. Control measures are: (1) hill selection of seed from visibly stem rot-free plants, (2) seed disinfection; (3) sanitation in and around the seed bed; and (4) rota-

tion in the event the field soil is heavily infested. The practice of feeding decayed or partially rotted sweet potatoes to livestock and using the manure in fields where sweet potatoes are to be planted is discouraged because this practice serves to disseminate the organism. Some varieties are resistant to or tolerant of stem rot but lack some of the desirable horticultural qualities possessed by more susceptible varieties. The Triumph, Red Brazil, Southern Queen, and Yellow Yam are somewhat resistant.

Fig. 10.—Stem rot of sweet potato, showing the discoloration of vascular tissue. (Courtesy, U. S. D. A.)

Scurf.—Sweet potato scurf although an exceedingly common disease causes a smaller loss than does black rot. The food value of infected potatoes is probably not impaired for the disease is usually only 'skin deep', but their unsightly appearance often results in a decrease of 25 to 50 per cent in price. Scurf-infected potatoes assume a brownish discoloration on the skin, sometimes scattered in irregular spots, sometimes covering almost the entire surface. The disease is less serious in light sandy than in the heavier soils, and is thought to be more severe in moist soils than in dry. When scurf-infected potatoes are bedded, the organism infects the young plants and the disease is then carried to the field. Control methods for black rot will serve to check scurf.

Soft Rot and Ring Rot.—These two diseases are caused by very closely related organisms but are characterized by different symptoms. Infection usually takes place through wounds and the disease develops

Fig. 11.—Soft rot, showing the moldy growth which often occurs on sweet potatoes in storage or transit. (Courtesy, U. S. D. A.)

in the storage house or in transit. As the name indicates, *soft rot* is manifested by rotting of the infected potatoes, which are at first rendered soft and stringy, water often dripping out when they are broken open. Often the soft rot organism causes a white, moldy growth on the surface of infected potatoes (fig. 11), producing spores in great abundance and making possible the dissemination of the organism to uninfected potatoes. *Ring rot* likewise produces a collar or ring of depression often extending entirely around the potato (fig. 12). The rot may extend entirely through the potato or only

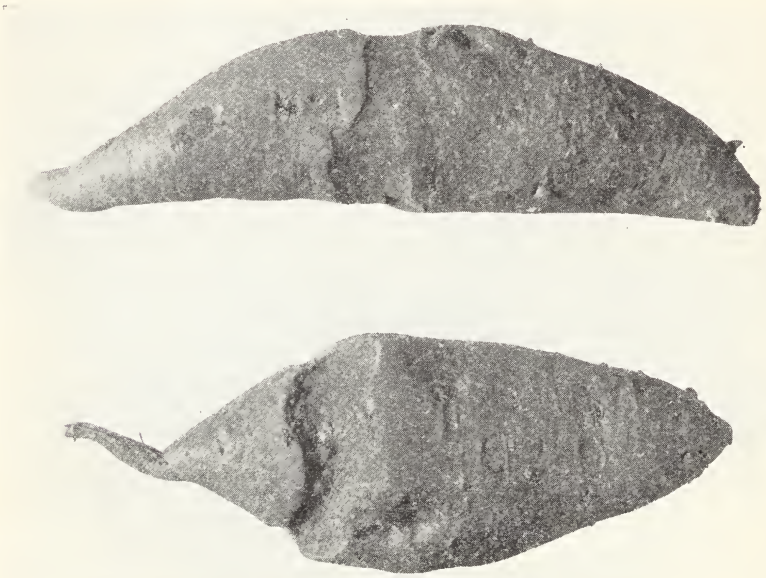

Fig. 12.—Ring-rot of sweet potato—caused by the same fungus as soft rot. (Courtesy, U. S. D. A.)

one-half inch beneath the skin. The organisms causing soft rot and ring rot are rather cosmopolitan in nature and cause rotting of vegetables other than sweet potatoes. Control measures consist of (1) careful handling of the potatoes to avoid mechanical injuries, (2) storage house disinfection or fumigation, and (3) proper curing and storing.

Foot Rot.—Sweet potato foot rot, while of widespread occurrence, is not so serious as either black rot or stem rot. It is present in California where it was particularly prevalent in 1917. The symptoms of this disease are similar to those produced by stem rot and black rot; indeed, this disease is often mistaken for stem rot. Control is effected by the same measures as those for stem rot.

Pox.—This disease, like foot rot, has been recognized for many years, but until recently the cause was unknown. The disease has been called pit, soil rot, and ground rot but the term *pox* is more descriptive of the symptoms produced. Pox-infected plants bear small, thin, pale-green leaves, which sometimes die prematurely. The root system is poorly developed and black, water-soaked lesions appear on the underground part of the stem and on the potatoes. Later these lesions become pitted, leaving a hole one-half inch or more in diameter. In severe cases of infection the potato may be more or less girdled, the disfiguration resembling a dumb-bell. The pits have irregular margins similar to common scab of the Irish potato. Control consists of rotation of crops and use of green manure crops on infested land.

Leaf Diseases.—Fortunately leaf diseases rarely cause serious damage to sweet potatoes, although several are known. White rust, leaf blight, leaf spot, and rust sometimes occur but are seldom severe enough to lower the yield under California conditions.

Miscellaneous Diseases.—In addition to the diseases described above, many others are known but rarely cause serious loss in California. Chief among these are Java black rot, mosaic, dry rot, charcoal rot, surface rot, rootlet rot, mottle necrosis, Texas root rot, and sclerotial blight.

Root-knot.—Root-knot of sweet potatoes is caused by a nematode or eelworm commonly found in light sandy soils. Some varieties of sweet potatoes are not seriously injured by root-knot but serve as a host for the nematodes in the rotation. In fact, very satisfactory crops of most varieties of the Jersey group can be grown on soils so thoroughly infested with nematodes that it is impossible to grow tomatoes, egg plant or melons with profit. Nematode injury appears as small galls on the fibrous roots and as larger galls on the root end of the potatoes. The disease is spread from one locality to another by nematode-infected plants and care should be taken not to plant infected plants in young orchards on sandy land where severe nematode infestation would have serious and permanent results.

There is marked variation in resistance of sweet potato varieties to root-knot. In 1924, Dr. J. L. Weimer,[3] found by extensive trials in southern California that while Nancy Hall and Red Brazil were very susceptible, the varieties Red Jersey, Yellow Jersey, Big Stem Jersey, Porto Rico, Southern Queen, and Yellow Belmont were highly resistant even when grown on sandy land severely infested with nematodes.

[3] Weimer, J. L. Varietal resistance of sweet potatoes to nematodes *Heterodera radicicola* (Greef) Müller, in California. Phytopathology **15**:423–426. 1925.

THE DISEASE CONTROL PROGRAM

This circular emphasizes the fact that profitable production of sweet potatoes is limited by the intelligent application of disease control measures. Sweet potatoes are exposed and liable to disease infection in the field, storage house, seed bed, in transit and in the market and home. Their keeping qualities are impaired by improper storage conditions. When improperly handled, they may become bruised and ideal conditions for disease infection provided. The seed bed is an ideal growing place not only for the young plants but for rapid growth and multiplication of disease-producing organisms. Infested field soil may remain so for a long period of time even though crops other than sweet potatoes are grown. Seed stock and plants shipped from one locality to another may serve to disseminate diseases, any one of which may be responsible for an epidemic. Hence disease control becomes of utmost importance to the grower, dealer, and consumer. Several preventive measures have been pointed out as usually necessary in order to control each disease. The following listed practices have proved their worth in many sweet potato sections and apply to California conditions:

1. At or before harvest time plow out and examine the individual hill for stem rot, black rot and scurf. Split the stem downward from the crown of the plant to the base of the stem and select seed only from those plants whose stems are not discolored inside. Place such seed in new or disinfected containers, handling as carefully as possible to avoid mechanical injury.

2. Regulate the temperature of the storage house so that it fluctuates between 80° and 86° F for a period of ten days to two weeks after the potatoes are placed in storage. Arrange the ventilating system to carry the moisture-laden air away as rapidly as possible. After the potatoes are properly cured, lower the temperature to 55° F and keep it there for the remainder of the storage period.

3. Before the seed stock is bedded, the potatoes should be sorted over, the visibly diseased ones discarded, and the remainder dipped for ten minutes in a solution made by adding one ounce of corrosive sublimate to eight gallons of water. For equipment see figure 3.

4. Use sand or light soil in preparing the hotbed, being careful to obtain it from a locality where sweet potatoes have never been grown. Never discard diseased potatoes near the storage house or hotbed where they may become sources of infection for the stored potatoes or the young plants in the hotbed. Be sure that containers for seed stock are new or, if old, have been disinfected in formaldehyde or copper sulfate. Fumigate the storage room before storing the crop.

5. Discard all plants which are diseased when pulled from the hotbed. Plants with blackened or blue stems are very probably diseased.

6. Whenever possible, grow sweet potatoes on land that has not produced this crop for several years.

7. Try to grow disease-free seed and plants at home rather than to buy them from other localities. This practice will tend to prevent the spread of diseases.